Missouri Department of Natural Resources

Biological Assessment Study

Big Creek
Iron County

2002 - 2003

Prepared for:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Pollution Control Program

Prepared by:

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1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MDNR**), Water Pollution Control Program (**WPCP**), the Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment of Big Creek in Iron County near Glover, Missouri. A seven mile segment of Big Creek was assessed, with one sampling station upstream and three downstream of Scroggins Branch, which contains the discharge of the Doe Run Glover Lead Smelter (NPDES permit number MO-0001121). These stations were compared with ESP's Biological Criteria for Perennial/Wadeable Streams database for the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (**EDU**).

1.1 Study Area/Justification

Big Creek originates in Iron County south of Taum Sauk Mountain. Big Creek is listed in the Missouri Water Quality Standards (MDNR 2000) as a class "C" stream for its first 0.5 mile and a class "P" stream for thirty-two miles to its confluence with the St. Francis River in Wayne County. Designated uses for Big Creek are "cool water fishery, warm water aquatic life protection, human health/fish consumption, whole body contact recreation, boating and canoeing, and livestock and wildlife watering." Four miles of Big Creek have been placed on the 1998 303(d) list for elevated levels of metals from discharges from the Doe Run Glover Lead Smelter. The lead smelter located in Glover, Missouri discharges into Scroggins Branch, a Big Creek tributary, and has a design flow of 638,000 gallons per day (gpd) or about 0.99 cubic feet per second (cfs).

Effluent from lead smelting activities may contain suspended and dissolved heavy metals. Previous studies on Big Creek and other streams in the United States around lead mining operations have demonstrated impact to aquatic communities. Ryck (1974) found that prior to the Glover lead smelter operation in the late 1960's, Big Creek near Chloride, Missouri had a high diversity of pollution sensitive macroinvertebrate taxa like mayflies and stoneflies, but by the early 1970's only pollution tolerant macroinvertebrate taxa were found at this site. Other studies on Big Creek have found that the fish and macroinvertebrate community were impaired (ENSR, 1997) and fish had elevated levels of heavy metals in their tissue and blood (Schmitt and Caldwell, 1997) below the Glover Lead Smelter. Studies from other ecological regions in the United States have found lowered percent composition or elimination of Ephemeroptera and increased abundance of Chironomidae (especially Orthocladiinae) and Hydropsychidae (net-spinning caddisflies) downstream from metals impacts in the absence of organic pollution (Clements, 1991).

In 2002, a study plan was submitted to the MDNR, WPCP (Appendix A). The ESP, WQMS was responsible for the proposed bioassessment study on Big Creek in Iron County that included the following purpose, objectives, tasks, and null hypotheses.

1.2 Purpose

The purpose of the study is to determine if Big Creek, Iron County is impaired by Doe Run Glover Lead Smelter.

1.3 Objectives

1) Determine if the discharge from the Doe Run Glover Lead Smelter is affecting the macroinvertebrate community and water quality in Big Creek.

2) Assess the habitat quality for Big Creek.

1.4 Tasks

1) Conduct a bioassessment of the macroinvertebrate community on Big Creek at one upstream and three downstream stations of the Doe Run Glover Lead Smelter discharge in Scroggins Branch, Iron County.

2) Conduct a water quality assessment at the sampling stations to determine potential water quality impacts.

3) Conduct a habitat assessment at the sampling stations to ensure comparability of aquatic habitats.

1.5 Null Hypotheses

1) The macroinvertebrate community will not differ between longitudinally separate reaches of Big Creek.

2) The macroinvertebrate community in Big Creek will not differ from similar sized reaches of biological criteria reference streams within the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU).

2.0 Methods

Carl Wakefield and Brian Nodine of the Water Quality Monitoring Section, Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program conducted this study.

2.1 Study Timing

Macroinvertebrate and water quality samples were collected for one fall and spring season. Fall sampling and habitat assessment were conducted on October 1 and 2, 2002 and spring sampling was conducted on March 25 and 26, 2003.

2.2 Station Descriptions

Figure 1 shows the location for the test and control (upstream control) stations and Table 1 provides legal descriptions and descriptive information for each station. For quality control purposes, duplicate samples were collected at stations #3 and #4 during the fall and spring, respectively. These duplicate samples are designated as 3a and 3b (fall) and 4a and 4b (spring).

Figure 1: Map of Big Creek and Sampling Stations

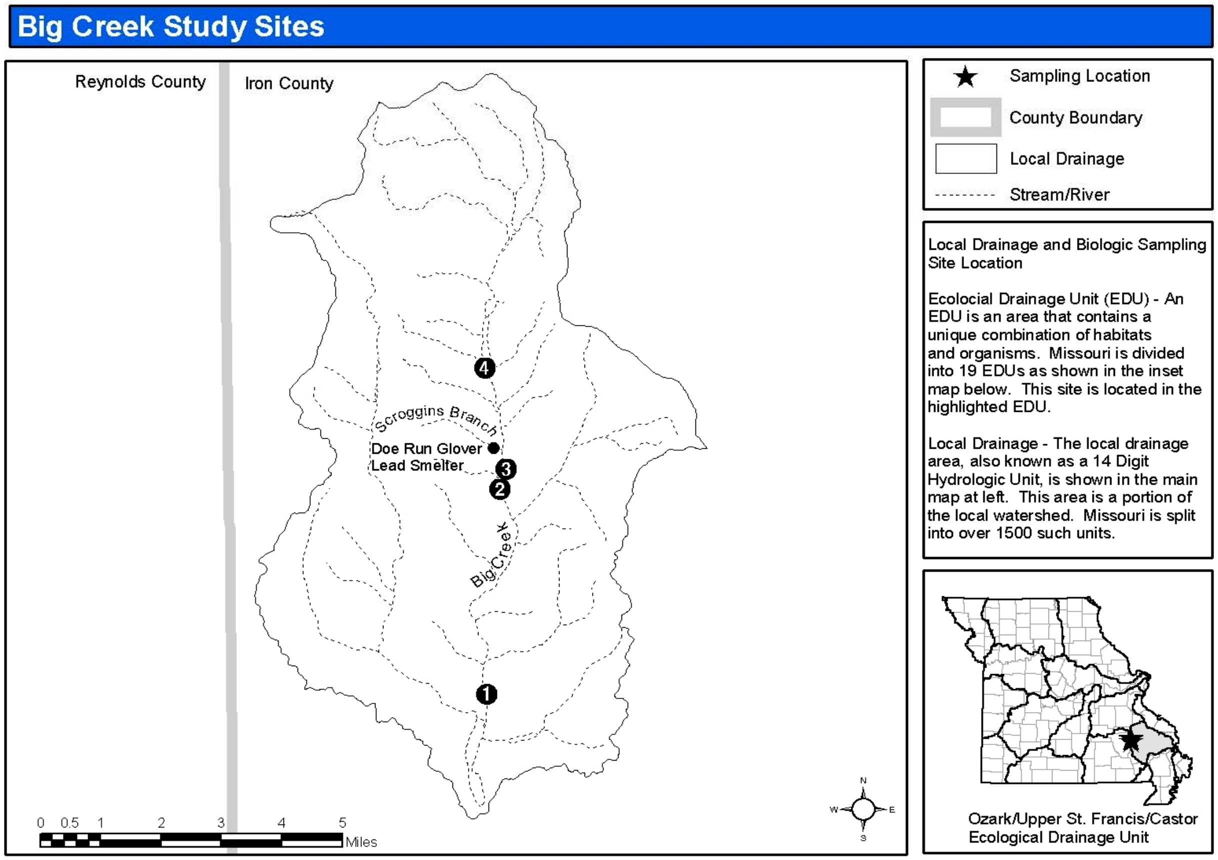

Table 1
Station Number, Legal Location, and Descriptive Information for the Big Creek Bioassessment Study

Station Number	Location ¼, Section, Township, Range	Description	County
Big Creek #1	NW ¼ sec. 35, T. 32 N., R. 3 E.	Test-5.0 Miles Downstream Scroggins Branch Confluence at Highway 49 bridge Crossing	Iron
Big Creek #2	SW ¼ sec. 11, T. 32 N., R. 3 E.	Test-0.5 Mile Downstream Scroggins Branch Confluence (303(d) listed segment)	Iron
Big Creek #3	NW ¼ sec. 11, T. 32 N., R. 3 E.	Test-0.1 Mile Downstream Scroggins Branch Confluence (303(d) listed segment)	Iron
Big Creek #4	SW ¼ sec. 35, T. 33 N., R. 3 E.	Contol-1.6 miles Upstream Scroggins Branch	Iron
Scroggins Branch	NW ¼ sec. 11, T. 32 N., R. 3 E.	Test-Doe Run Glover Lead Smelter Discharge*	Iron

*Water Quality Only

2.2.1 Ecological Drainage Unit

An EDU is a region in which biological communities and habitat conditions can be expected to be similar. A map of the Ozark/St. Francis/Castor EDU is also included in Figure 1. All stations are within this EDU. Table 2 compares the land cover percentages from the Ozark/St. Francis/Castor EDU and the 14-digit Hydrologic Unit (**HU**), #08020202040001, which contains the Big Creek study reach. Land cover data were derived from Thematic Mapper (**TM**) satellite data from 1991 to 1993 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**). Forest is the dominant land cover of the Big Creek watershed and the Ozark/St. Francis/Castor EDU (Table 2).

Table 2
Percent Land Cover

Land Cover	Urban	Crops	Grassland	Forest	Swamp
EDU	0.1	6	28.7	63.7	0
Big Creek and Scroggins Branch	0	0	6	92.3	0

2.3 Habitat Assessment

A standardized assessment procedure was followed as described for Riffle/Pool Habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (2003a). The habitat assessment was conducted on all stations during the October 2002 sampling season.

2.4 Biological Assessment

Biological assessments consist of macroinvertebrate collection and physicochemical sampling for the two sample periods.

2.4.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (2003b). Three standard habitats (flowing water over coarse substrate, depositional substrate in non-flowing water, and root-mat) were sampled at all locations.

Macroinvertebrate data were analyzed using two methods. The first analysis was using the four general biological metrics found in the SMSBPP. The four metrics used and found in SMSBPP are: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/ Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). The metric evaluations were done by comparing Big Creek sample stations on a seasonal basis to ESP's Biological Criteria for Perennial/Wadeable Streams Database. The database uses minimally to unimpaired reference stream stations within the Ozark/Upper St. Francis/Castor EDU. The second analysis of the biological data was an evaluation of macroinvertebrate community composition by percent composition of different macroinvertebrate groups in the order Ephemeroptera, the family Chironomidae, other taxonomic groups, and metal sensitivity tolerances for these taxonomic groups.

2.4.2 Physicochemical Collection and Analysis

Results are shown from physicochemical collections and analyses during each of the sampling periods during 2002 and 2003.

Physicochemical samples collected in October 2002 and March 2003 were: pH, temperature, conductivity, dissolved oxygen, discharge, turbidity, hardness, ammonia-N, nitrate/nitrite-N, Total Kjeldahl Nitrogen (TKN), chloride, total phosphorus, dissolved calcium, cadmium, copper, iron, magnesium, lead, and zinc. Temperature, pH, conductivity, dissolved oxygen, and discharge were conducted in the field. The samples were collected at the four sample stations in Big Creek and Scroggins Branch which receives the discharge of the Doe Run Glover Lead Smelter.

All samples were collected per MDNR-FSS-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations (MDNR 2003e). All samples were kept on ice until they were delivered to the ESP laboratory. The WQMS measured turbidity in the WQMS Biology Laboratory. All other samples were delivered to the ESP Chemical Analysis Section (CAS) for analyses.

Results of water quality analyses were compared to Water Quality Standards (MDNR 2000). Big Creek is classified as a Class P stream and a general warm-water fishery (GWWF) and cool water fishery (CWF) for the study reach. Waters designated as CWF "allow the maintenance of a sensitive, high quality sport fishery (including smallmouth bass and rock bass)".

Two other criteria were included to identify limits. The first criterion was the reason for protection. In this case, values were identified for the "Protection of Aquatic Life". The second was the rate of exposure, such as chronic or acute exposure. This was important to determine limits for pollutants that could be tolerated by aquatic life over a period of time.

2.4.3 Discharge

Stream flow was measured using a Marsh-McBirney Flow Meter at each station and discharge was calculated as cubic feet per second (cfs). Methodology was in accordance with the standard operating procedure MDNR-WQMS 113, Flow Measurement in Open Channels (MDNR 2003d).

2.5 Data Analysis

The physicochemical data were examined by variable to identify stations that had elevated levels that were above or below Missouri Water Quality Standards (MDNR 2000). Sampling stations that had elevated levels of certain variables were then discussed with possible influences being identified.

2.6 Quality Control

Quality control was used as stated in the various MDNR Project Procedures and Standard Operating Procedures. Duplicate samples #3b and #4b were collected and analyzed for macroinvertebrate and physicochemical parameters. A random number of macroinvertebrate collections were rechecked for missed specimens.

3.0 Results and Analysis

Three areas of interest may identify impacts to the streams. A physical habitat assessment, biological assessment, and physicochemical water analysis were completed.

3.1 Habitat Assessment

Table 3 provides habitat assessment scores for Big Creek stations. Data were collected in October 2002 and Carl Wakefield and Brian Nodine did all the scoring. According to the SHAPP, for a study site to fully support a biological community, the total score of the study site should be 75 to 100 percent similar to the total score of a reference site. All of the test stations had higher habitat scores than the upstream control site. These scores suggest that the test stations should be able to support a macroinvertebrate community comparable to the control station.

Table 3
Habitat Assessment Scores for Control and Test Stations, October 2002

Control Stream/Station	Habitat Score	Test Streams/Stations	Habitat Score	% of Control
Big Creek #4	117	Big Creek #1	126	108
		Big Creek #2	125	107
		Big Creek #3	149	127

3.2 Biological Assessment

Macroinvertebrate data were evaluated by two methods. The first analysis was using the general biological metrics in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP) and the proposed Biological Criteria for Wadeable Perennial Streams (MDNR 2002). The second analysis of the biological data was an evaluation of macroinvertebrate community composition using percent composition of predominant macroinvertebrate taxa and metal sensitivity tolerances of macroinvertebrate taxa.

3.2.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)

The SMSBPP metric evaluation used numeric biocriteria that were calculated from the ESP's Biological Criteria for Wadeable and Perennial Streams database within the Ozark/Upper St. Francis/Castor EDU. The criteria are listed for the fall and spring seasons in Tables 4 and 5.

Table 4
Biological Criteria Database Scores for Warm Water Reference Streams Within Ozark/Upper St. Francis/Castor EDU, Fall Season

	Score = 5	Score = 3	Score = 1
TR	>87	87-44	43-0
EPTT	>21	21-10	9-0
BI	<5.98	5.98-7.99	8.00-10
SI	>3.36	3.36-1.68	1.67-0

Table 5
Biological Criteria Database Scores for Warm Water Reference Streams Within Ozark/Upper St. Francis/Castor EDU, Spring Season

	Score = 5	Score = 3	Score = 1
TR	>93	93-47	46-0
EPTT	>27	27-14	13-0
BI	<5.92	5.92-7.96	7.97-10
SI	>3.31	3.31-1.65	1.64-0

The metric values and scores for Big Creek from fall 2002 are presented in Table 6. Data from the fall 2002 samples showed that Big Creek #4 and Big Creek #2 had full sustainability while Big Creek #3a, Big Creek #3b, and Big Creek #1 had partial sustainability based on metric scores. Taxa Richness was reduced very minimally at test stations #2, #3a, and #3b compared to control station #4 and test station #1 (Table 6). EPT taxa was reduced from 24 at station #4 to 17 at station #3a and #3b, and increased to 20 at station #2 and 22 at station #1. Biotic Index scores of 6.11 at stations #3a and #3b were substantially higher than the score of 5.73 at station #2 and the score of 5.84 at station #4. The Biotic Index score of 6.09 at station #1 approached values found at stations #3a and #3b. Shannon Diversity Index ranged from 3.29 to 3.60, with the lowest value occurring at station #1 and the highest value occurring at station #4.

Table 6
Big Creek Metric Values and Scores, Using Biological Criteria Database for Stations in the Ozark/Upper St. Francis/Castor EDU
October 2002

Sample No./Station	TR	EPTT	BI	SI	T-Score	Sustain.
02-18116						
Big Ck. #4 Value	82	24	5.84	3.60		
Big Ck. #4 Score	3	5	5	5	18	Full
02-18117						
Big Ck. #3a Value	81	17	6.11	3.55		
Big Ck. #3a Score	3	3	3	5	14	Partial
02-18118						
Big Ck. #3b Value	76	17	6.11	3.33		
Big Ck. #3b Score	3	3	3	3	12	Partial
02-18119						
Big Ck. #2 Value	74	20	5.73	3.52		
Big Ck. #2 Score	3	3	5	5	16	Full
02-18120						
Big Ck. #1 Value	86	22	6.09	3.29		
Big Ck. #1 Score	3	5	3	3	14	Partial

The metric values and scores for Big Creek from spring 2003 are presented in Table 7. Data from the spring 2003 samples showed that the duplicate samples at the upstream control Big Creek #4 (#4a and #4b) had full sustainability and all of the test stations had partial sustainability based on metric scores. Taxa Richness, EPT taxa, and the SDI decreased and the Biotic Index increased at all of the test stations compared to the upstream control stations. Taxa Richness was slightly reduced at test stations #1 and #3 and greatly reduced at station #2 compared to the control stations (Table 7). EPT taxa was reduced from 33 at station #4a and 34 at station #4b to 26 at station #3, 25 at station #2, and 27 at station #1. Biotic Index scores were substantially higher at the test stations than the upstream control stations with the highest value occurring at station #1 (Table 7). The SDI was also higher at the upstream control stations with the lowest value occurring at station #1.

Table 7
Big Creek Metric Values and Scores, Using Biological Criteria Database for Stations in the Ozark/Upper St. Francis/Castor EDU
March 2003

Sample No./Station	TR	EPTT	BI	SI	T-Score	Sustain.
03-18677						
Big Ck. #4a Value	89	33	4.91	3.48		
Big Ck. #4a Score	3	5	5	5	18	Full
03-18678						
Big Ck. #4b Value	97	34	4.86	3.62		
Big Ck. #4b Score	5	5	5	5	20	Full
03-18679						
Big Ck. #3 Value	84	26	5.61	3.27		
Big Ck. #3 Score	3	3	5	3	14	Partial
03-18680						
Big Ck. #2 Value	74	25	5.79	3.27		
Big Ck. #2 Score	3	3	5	3	14	Partial
03-18681						
Big Ck. #1 Value	88	27	6.23	3.12		
Big Ck. #1 Score	3	3	3	3	12	Partial

3.2.2 Macroinvertebrate Percent and Community Composition

The number of total taxa, EPT taxa, percent EPT, and percent composition for the five dominant macroinvertebrate families (DMF) at each station are presented in Tables 8 and 9. Values in the tables in bold type represent the five dominant macroinvertebrate families for each station.

Fall 2002 macroinvertebrate samples from Big Creek showed that EPT taxa decreased downstream of Scroggins Branch and slowly began to recover at Big Creek #1. Mayflies made up a large percentage of the EPT taxa at station #4 (control station), declined dramatically at stations #2, #3a, and #3b, and began to recover at station #1 (Table 8 and Figure 2). Heptageniidae and Caenidae made up a large proportion of the sample collected at station #4, but these mayfly families made up less than 1 percent of the sample at test stations #2, #3a, and #3b. These two mayfly families began to recover at test station #1 but at lower levels than were found at station #4 (Table 8 and Figure 2). Mayfly taxa richness declined from 17 taxa at station #4 to 4 taxa at station #3 and 5 taxa at station #2, then began to recover at station #1 with a taxa richness of 14.

The dominant macroinvertebrate families show impairment at test stations #2, #3a, and 3b compared to control station #4 (Table 8). Chironomidae was the most abundant family at all stations and increased from 38.17 percent at station #4 to 52.71-63.15 at stations #2, #3a, and #3b (Table 8 and Figure 3). The chironomid tribe Orthocladinae, including the tolerant *Cricotopus bicintus*, increased at test stations #2, #3a, and #3b compared to control station #4

and test station #1. The tribe Tanytarsini was lower in percent composition at test stations #3a and #3b than at other stations (Figure 3). Other dipterans of the families Empididae, Simuliidae, and Tipulidae were more abundant at test stations #2, #3a, and #3b than upstream control station #4 (Table 8).

Chironomidae, Heptageniidae, Caenidae, Hyalellidae, and Psephenidae were the most dominant families at control station #4 while Coengrionidae, Leptoceridae, Hydropsychidae, Elmidae, Tipulidae, Simuliidae, and Empididae were more abundant at test stations #2, #3a, and #3b. The most dominant families at test station #1 after Chironomidae were Caenidae, Elmidae, Hydropsychidae, and Ceratopogonidae (Table 8).

Spring 2003 macroinvertebrate samples from Big Creek showed that EPT taxa decreased downstream of Scroggins Branch. Mayflies made up a larger percentage of the macroinvertebrate sample at upstream control stations #4a and #4b than test stations #2 and #3, but was substantially higher at test station #1 (Table 9 and Figure 4). Caenidae, Heptageniidae, and Ephemerellidae made up most of the mayflies found at the upstream control stations and declined substantially at test stations #2 and #3 (Figure 4). Caenidae made up 24.51 percent of the macroinvertebrate sample at test station #1, accounting for most of the increase of mayflies at this station, and Heptageniidae increased to levels higher than upstream control stations #4a and #4b. Mayfly taxa richness declined from 15 at station #4a and 16 at station #4b to 11 at station #3 and 6 at station #2, then began to recover at station #1 with a taxa richness of 13.

The dominant macroinvertebrate families in the spring 2003 samples showed impairment at test stations #2 and #3 as compared to upstream control stations #4a and #4b (Table 9). Chironomidae was the most abundant family at all stations and was higher at test stations #2 and #3 than the upstream control stations and test station #1 (Table 9 and Figure 5). The chironomid tribe Orthocladinae, including the tolerant *Cricotopus bicintus*, increased and the tribe Tanytarsini decreased at test stations #2 and #3 compared to upstream control stations #4a and #4b (Figure 5). The trichopteran family Hydroptilidae and dipterans of the families Empididae and Tipulidae were more abundant at test stations #2 and #3 than the other sampling stations (Table 9). Leuctridae was the third most abundant family at the upstream control stations, but declined substantially at all of the test stations. Hydropsychidae was higher at the upstream control stations and test station #1 than test stations #2 and #3 (Table 9).

Chironomidae, Perlodidae, Leuctridae, Nemouridae, Hydropsychidae, and Caenidae were the most dominant families at the upstream control stations while Perlodidae, Nemouridae, Empididae, Tipulidae, and Hydroptilidae were more abundant at test stations #2 and #3. The most dominant families at test station #1, after Chironomidae, were Caenidae, Hydropsychidae, Tipulidae, Elmidae and Heptageniidae (Table 9).

Table 8
Big Creek Control and Test Stations. Macroinvertebrate Composition per Station, October 2002

Variable-Station	Big Creek #4, Control Station	Big Creek #3a, Test Station	Big Creek #3b, Test Station	Big Creek #2, Test Station	Big Creek #1, Test Station
Macro Sample Number	02-18116	02-18117	02-18118	02-18119	02-18120
Total Richness	82	81	76	74	86
Number EPT Taxa	24	17	17	20	22
% Ephemeroptera	35.51	1.33	1.02	1.58	26.77
% Plecoptera	1.45	0.62	0.51	0.79	1.16
% Trichoptera	4.52	12.72	6.24	17.95	7.32
% Dominant Macroinvertebrate Families (DMF; below)					
Chironomidae	**38.17**	**56.54**	**63.15**	**52.63**	**26.93**
Heptageniidae	**16.38**	0.09	0.61	0.18	3.57
Caenidae	**10.33**	0.35	0.20	0.44	**19.45**
Hyalellidae	**3.87**	0	0	0	4.41
Psephenidae	**2.99**	1.41	1.02	0.96	1.08
Coenagrionidae	2.74	**6.45**	**5.12**	**3.68**	1.66
Elmidae	2.50	**5.48**	2.76	**3.68**	**18.37**
Leptoceridae	0	**4.68**	1.43	**7.18**	1.41
Hydropsychidae	2.91	**3.45**	2.56	**7.01**	**5.57**
Tipulidae	0.16	1.59	**5.22**	2.98	1.91
Simuliidae	0	1.50	**5.12**	**7.27**	0.17
Empididae	1.05	2.30	**3.17**	2.71	0.25
Ceratopogonidae	1.29	2.30	0.82	0.53	**4.82**

Figure 2
Percent Composition of Mayfly Groups at Each Station, October 2002

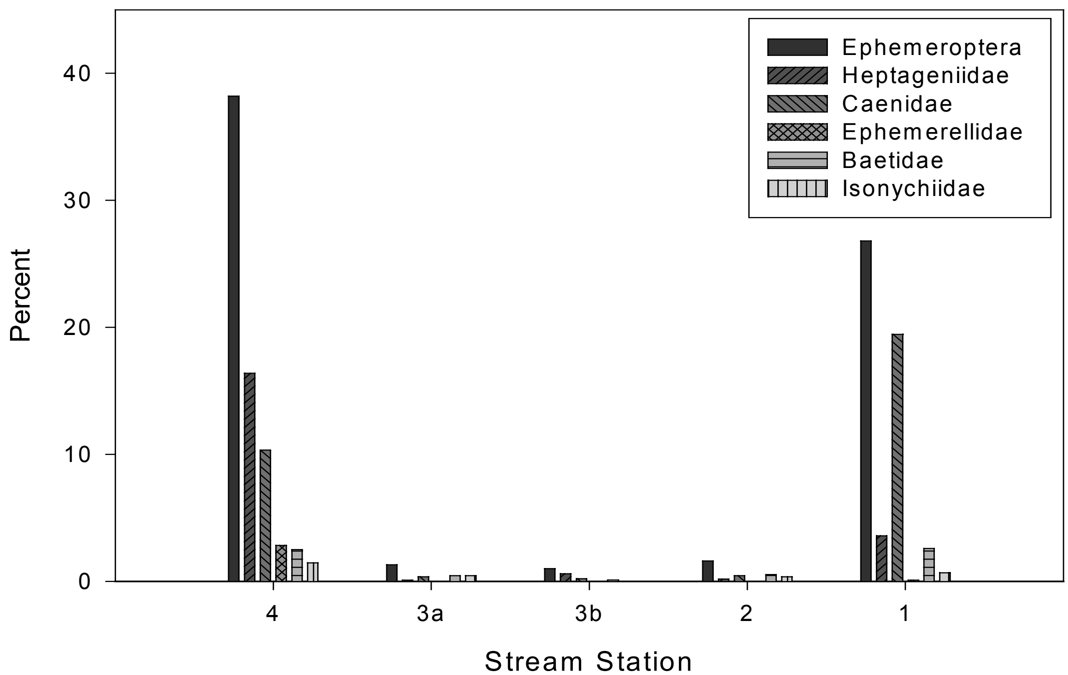

Figure 3
Percent Composition of Dipteran Groups at Each Station, October 2002

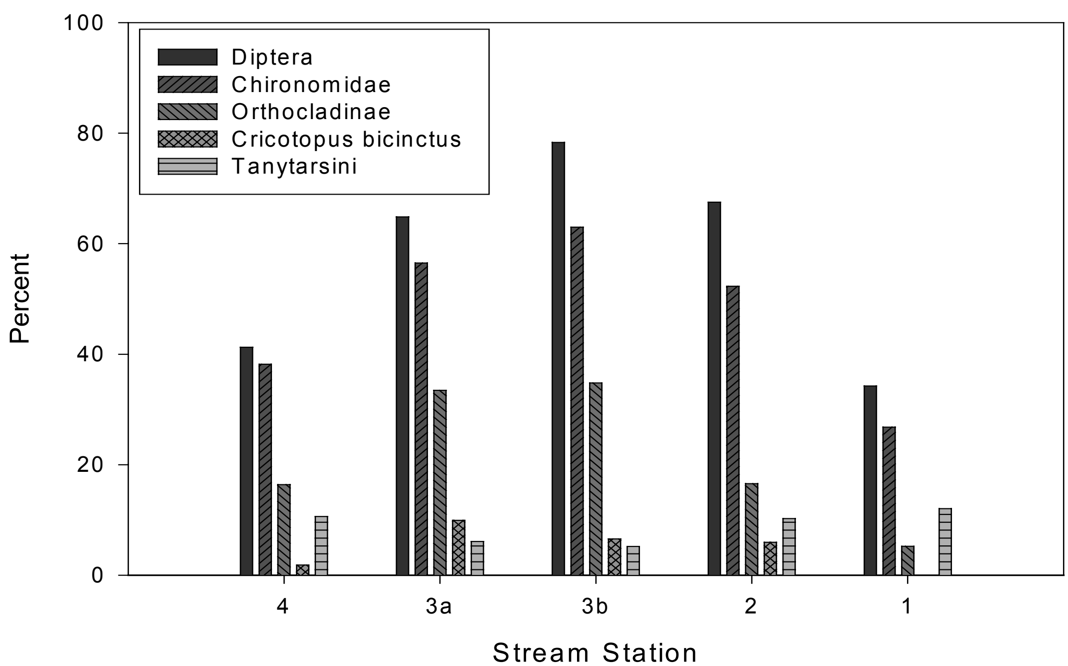

Figure 4
Percent Composition of Mayfly Groups at Each Station, March 2003

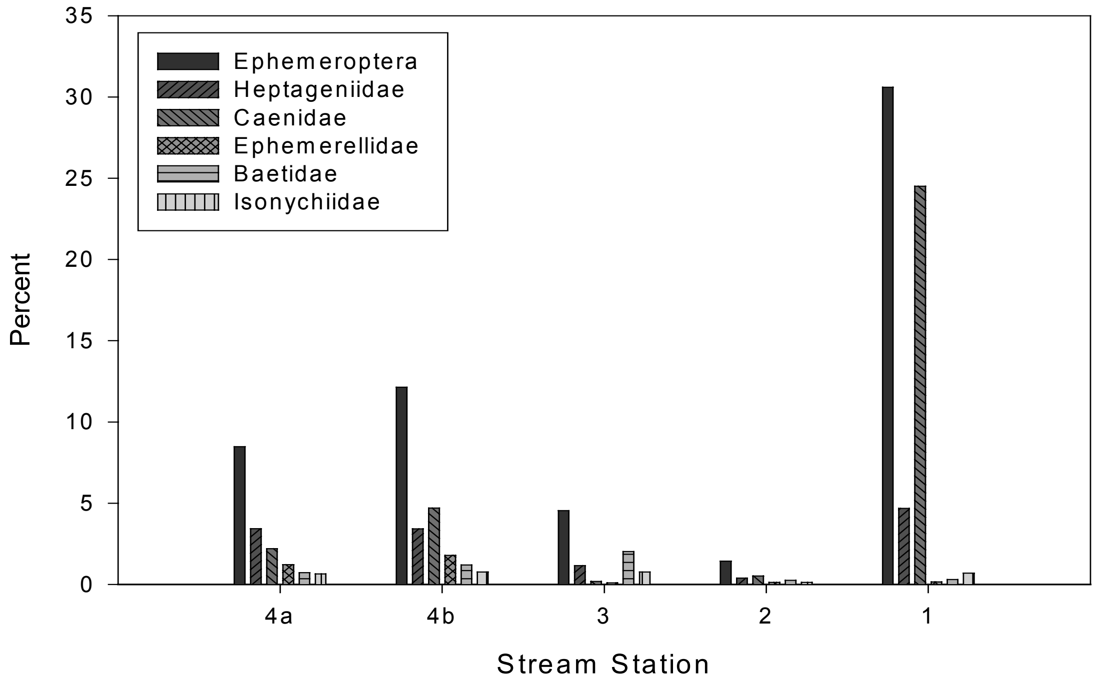

Figure 5
Percent Composition of Dipteran Groups at Each Station, March 2003

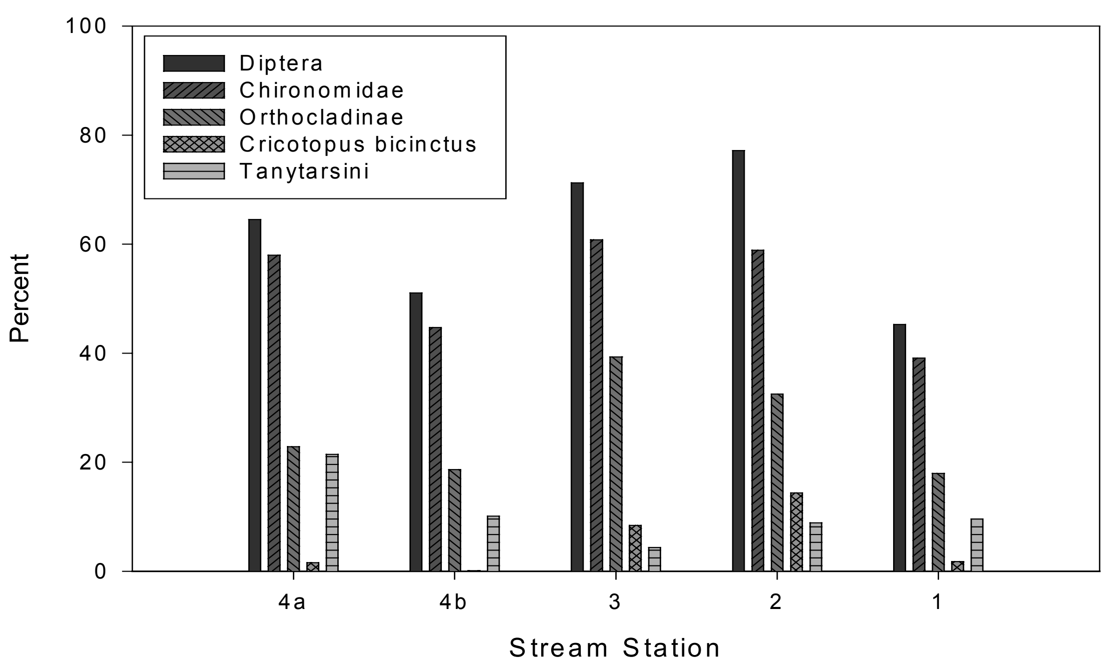

Table 9
Big Creek Control and Test Stations. Macroinvertebrate Composition per Station, March 2003

Variable-Station	Big Creek #4a, Control Station	Big Creek #4b, Control Station	Big Creek #3, Test Station	Big Creek #2, Test Station	Big Creek #1, Test Station
Macro Sample Number	03-18677	03-18678	03-18679	03-18680	03-18681
Total Richness	89	97	84	74	88
Number EPT Taxa	33	34	26	25	27
% Ephemeroptera	8.48	12.14	4.55	1.44	30.60
% Plecoptera	18.11	23.08	13.26	7.05	2.26
% Trichoptera	6.28	8.12	4.84	8.36	9.45
% Dominant Macroinvertebrate Families (DMF; below)					
Chironomidae	**57.99**	**44.70**	**60.79**	**58.88**	**39.11**
Perlodidae	**6.61**	**10.60**	**6.20**	1.70	1.01
Leuctridae	**5.38**	**5.98**	0.1	0.13	0
Nemouridae	**4.49**	**5.81**	**5.23**	**3.92**	0
Hydropsychidae	**3.67**	**4.70**	1.26	0.52	**6.95**
Caenidae	2.20	**4.70**	0.19	0.52	**24.51**
Empididae	2.28	2.48	**4.94**	**5.22**	0.55
Simuliidae	1.96	2.14	**3.00**	0.39	0.08
Tipulidae	1.39	0.60	1.94	**10.97**	**4.68**
Hydroptilidae	0.33	0.17	1.74	**4.05**	0.94
Elmidae	0.08	0.51	0.39	3.52	**5.78**
Heptageniidae	3.43	3.42	1.16	0.39	**4.68**

3.2.3 Physicochemical Water

Physicochemical results are arranged to demonstrate trends of certain variables that may identify a source for impacts to Big Creek. Results can be found in Table 10 for October 2002 samples and in Table 11 for March 2003 samples. These tables compare upstream control stations to downstream test stations and demonstrate the extent of dispersion of the physiochemical variables at downstream test stations. Results for quality control, discharge, dissolved cadmium, and dissolved zinc are discussed by season.

3.2.3.1 Quality Control

Big Creek #3a and #3b of October 2002 samples (Table 10) and Big Creek #4a and #4b of March 2003 samples (Table 11) were duplicate water quality samples. Results from these duplicates were similar and indicated that sampling, transport, processing, and analyses of samples were consistent as well as precise.

3.2.3.2 Discharge

Discharge during the October 2002 sample season was relatively low (Table 10). It ranged from 0.35 cfs at Big Creek #4 to 5.08 cfs at Big Creek #1. Scroggins Branch had a discharge of 0.93 cfs.

Discharge was much higher during the March 2003 sample season (Table 11). It ranged from 28.4 cfs at Big Creek #4 to 55.4 cfs at Big Creek #1. Scroggins Branch had a discharge of 2.04 cfs.

3.2.3.3 Metals

Overall, two dissolved metals were found within the stream stations. Results from one or both sample seasons show trends in the concentrations of dissolved cadmium and zinc at sampling stations.

3.2.3.3.1 Cadmium

Dissolved cadmium results were below detectable limits at upstream control station #4 and test station #1, but were elevated in Scroggins Branch and test stations #2, #3a, and #3b during the October 2003 sample season (Table 10). The elevated level of cadmium in the Big Creek stations was below the Water Quality Standards (MDNR 2000) chronic value of 11.8 ug/L and the acute value of 49.0 ug/L. Scroggins Branch is an unclassified stream and these criteria do not apply even though dissolved cadmium levels (23.6 ug/L) were higher than the chronic value for the General Warm Water Fishery (GWWF) classification.

Dissolved cadmium results were below detectable limits at all sample stations except Scroggins Branch (11.1 ug/L) during the March 2003 sample season (Table 11). Higher discharge during this sampling season could have resulted in lower dissolved cadmium concentrations.

3.2.3.3.2 Zinc

Dissolved zinc results were below detectable limits at upstream control station #4 and test station #1, but were elevated in Scroggins Branch and at test stations #2, #3a, and #3b during the October 2002 sample season (Table 10). The elevated levels of zinc in the Big Creek stations were below the Water Quality Standards (MDNR 2000) chronic value of 433 ug/L and the acute value of 479 ug/L. Scroggins Branch had a highly elevated level of dissolved zinc at 586 ug/L even though these criteria do not apply to unclassified streams.

Dissolved zinc results were below detectable limits at upstream control stations #4a and #4b and above detectable limits at all other sampling stations during the March 2003 sampling season (Table 11). The elevated levels of zinc in the Big Creek study stations were below the Water Quality Standards criteria (MDNR 2000) for chronic and acute toxicity. The dissolved zinc value of 774 ug/L in Scroggins Branch was highly elevated even though these criteria do not apply to unclassified streams.

Table 10
Physicochemical Variables for Big Creek Study in October 2002
Units mg/L unless otherwise noted.

Variable-Station	Big Creek #1, Test October 2002	Big Creek #2, Test October 2002	Big Creek #3a, Test October 2002	Big Creek #3b, Test October 2002	Big Creek #4, Reference October 2002	Scroggins Branch, Test October 2002
Physicochemical Sample Number	02-26531	02-26530	02-26528	02-26529	02-26526	02-26527
Sample Date	10/02/02	10/01/02	10/02/02	10/02/02	10/01/02	10/02/02
Sample Time	0950	1500	1410	1425	1145	1330
pH (Units)	7.90	7.83	8.10	8.14	7.82	8.02
Temperature (C^0)	19.5	21.5	24.0	24.0	21.5	28.5
Conductivity (uS)	342	357	361	362	234	493
Dissolved O_2	7.80	8.00	8.70	8.70	9.20	7.60
Discharge (cfs)	5.08	2.01	2.22	2.22	0.93	0.35
Turbidity (NTUs)	1.81	3.31	<1	<1	1.66	1.09
Hardness $CaCO_3$	164	163	164	163	109	236
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05	6.70
Nitrate/Nitrite-N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
TKN	<0.2	0.22	<0.2	<0.2	<0.2	<0.2
Chloride	<5	6.11	6.85	6.80	<5	<5
Total Phosphorus	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Calcium, Dissolved	34.8	34.3	34.8	34.6	22.6	50.1
Cadmium, Dissolved ug/L	<1	2.98	3.85	3.94	<1	23.6
Copper, Dissolved ug/L	<10	<10	<10	<10	<10	<10
Iron, Dissolved ug/L	11.9	<10	<10	<10	<10	<10
Magnesium, Dissolved	18.6	18.8	18.8	18.6	12.7	27.0
Lead, Dissolved ug/L	<2	<2	<2	<2	<2	6.70
Zinc, Dissolved ug/L	<10	53.9	68.1	67.7	<10	586

Table 11
Physicochemical Variables for Big Creek Study in March 2003
Units mg/L unless otherwise noted.

Variable-Station	Big Creek #1, Test March 2003	Big Creek #2, Test March 2003	Big Creek #3, Test March 2003	Big Creek #4a, Test March 2003	Big Creek #4b, Reference March 2003	Scroggins Branch, Test March 2003
Physicochemical Sample Number	0300805	0300804	0300803	0300800	0300801	0300802
Sample Date	03/25/03	03/24/03	03/24/03	03/24/03	03/24/03	03/24/03
Sample Time	0940	1650	1510	1115	1130	1440
pH (Units)	8.18	8.46	8.56	8.33	8.35	8.47
Temperature (C^0)	11.5	15.0	15.0	11.5	12.0	21.0
Conductivity (uS)	206	177	179	126	126	696
Dissolved O_2	10.30	8.17	8.21	11.30	11.40	6.72
Discharge (cfs)	55.4	31.4	32.3	28.4	28.4	2.04
Turbidity (NTUs)	1.40	1.42	1.50	1.83	1.95	1.01
Hardness $CaCO_3$	88.00	73.2	75.2	58.9	56.1	236
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate/Nitrite-N	0.06	<0.05	<0.05	<0.05	<0.05	0.13
TKN	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloride	6.36	6.99	6.88	6.18	6.08	11.9
Total Phosphorus	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Calcium, Dissolved	18.6	15.5	16.0	11.8	11.2	62.0
Cadmium, Dissolved ug/L	<1	<1	<1	<1	<1	11.1
Copper, Dissolved ug/L	<10	<10	<10	<10	<10	<10
Iron, Dissolved ug/L	<10	<10	<10	12.3	10.8	<10
Magnesium, Dissolved	10.10	8.37	8.57	7.16	6.84	19.6
Lead, Dissolved ug/L	<2	<2	<2	<2	<2	7.37
Zinc, Dissolved ug/L	16.60	42.0	45.6	<10	<10	774

4.0 Discussion

The discussion describes possible effects of stream habitat and physicochemical conditions on the biological metric scores and the macroinvertebrate community composition.

4.1 Habitat Assessment

Results of the stream habitat assessment of October 2002 suggest that the test stations should be comparable to the control station in their ability to support a similar quality macroinvertebrate community. Differences in biological metric scores and the macroinvertebrate community composition were probably not due to the habitat quality.

4.2 Dissolved Metals Effects on Biological Metric Scores

It is possible that dissolved metals were one of the causes of impairment at test stations #2 and #3. Results from the water samples during the study showed that dissolved cadmium and zinc were higher in October 2002 and dissolved zinc was higher in March 2003 at test stations #2 and #3 compared to control station #4 (Tables 10 and 11). These results were below the Water

Quality Standards (MDNR 2000) values for acute and chronic toxicity. Scroggins Branch had elevated levels of cadmium, lead, and zinc in October 2002 and March 2003 sample seasons. Dissolved metals were not elevated at test station #1 except for dissolved zinc (16.60 ug/L) during the March 2003 sample season.

During the fall 2002 sampling season, Big Creek #2 was the only test station that was assessed to be fully sustainable based on the stream condition index. This station, like test stations #3a and #3b, had lower mayfly abundance and richness while chironomids from the tribe Orthocladinae were higher than the upstream control station #4 (Figures 2 and 3). The primary difference between test station #2 and test stations #3a and #3b was that station #2 had a much lower Biotic Index (Table 6). Test station #2 had a higher abundance of intolerant or moderately tolerant groups from Hydropsychidae, Leptoceridae, and *Simulium* while tolerant groups from Chironomidae and Coenagrionidae were lower in abundance than test stations #3a and #3b, which probably accounted for the lower Biotic Index at station #3 (Table 8). *Ceratopsyche morosa* group (Biotic Index value of 2.95) of the family Hydropsychidae and *Triaenodes* (Biotic Index value of 3.7) of the family Leptoceridae were much higher in abundance while *Argia* (Biotic Index value of 8.7) of the family Coenagrionidae was lower in abundance at test station #2 than test stations #3a and #3b. It is not surprising that caddisflies were fairly abundant at test station #2 since previous studies have found that caddisfly abundance and richness, especially Hydropsychidae, were tolerant to heavy metal contamination (Clements et al., 2000; Clements et al., 1988).

Biological metric data showed that EPTT and the SDI decreased and the Biotic Index increased at test stations except for the Biotic Index at test station #2 in fall 2002 (Tables 6 and 7). Taxa Richness declined at test stations #2 and #3, but increased to levels similar to upstream control station #4 at test station #1 for both sampling seasons. The decline in EPT taxa was primarily caused by lower mayfly diversity at test stations #2 and #3 while the increase in Biotic Index was primarily caused by an increase in dipterans at these sites. Stoneflies and caddisflies declined slightly or increased at test stations #2 and #3. Previous studies have found that many stonefly and caddisfly families are tolerant to heavy metal pollution (Clements et al., 2000; Clements et al., 1988). Clements et al. (2000) found that stonefly abundance, stonefly richness, and caddisfly richness were impaired only at stream sites with very high levels of heavy metal pollution and caddisfly abundance was not impaired at any level of heavy metal pollution in the rocky mountain region of Colorado. Test station #1 EPT taxa values approached levels found at control station #4, while Biotic Index values were much higher than control station #4. The high Biotic Index values at this site were probably being driven by high relative densities of Caenidae and Ceratopogonidae for the fall 2002 season and by Caenidae and Tipulidae for the spring 2003 sampling season even though chironomid levels were lower than other sampling sites (Tables 8 and 9).

4.3 Dissolved Metals Effects on the Macroinvertebrate Community Composition

The decline in mayfly taxa richness and abundance indicated that dissolved metals were impairing the macroinvertebrate community at test stations #2 and #3. Previous studies have

shown that mayfly taxa richness and abundance, especially mayfly families Heptageniidae and Ephemerellidae, substantially decline in streams impacted by heavy metal pollution (Clements et al., 1988; Clements et al., 1992; Clements, 1994; Clements et al., 2000). Test stations #2 and #3 showed a substantial decline in mayfly taxa richness and abundance for most of the mayfly families for both the October 2002 and March 2003 sample seasons (Figures 2 and 4). Heptageniidae and Caenidae, the most abundant mayfly families, declined dramatically at stations #2 and #3 during the October 2002 sample season. During the March 2003 sample season, Heptageniidae, Caenidae, and Ephemerellidae declined at stations #2 and #3. Mayfly taxa richness and abundance were similar at stations #2 and #3 during the October 2002 sample season, but mayfly taxa richness and abundance were higher at station #3 than station #2 during the March 2003 sample season. The mayfly families Heptageniidae and Caenidae began to recover at station #1 with Caenidae making up a large proportion of the samples for both sampling seasons (Figures 2 and 4).

Test stations #2 and #3 also showed an increase in dipteran abundance in groups like Orthocladinae, Empididae, and Tipulidae and a decrease in Tanytarsini (Figures 3 and 5; Tables 8 and 9). Previous studies have found that Orthocladinae were tolerant and Tanytarsini were intolerant at sites impacted by dissolved copper and zinc (Clements et al., 1988; Clements et al., 1992). The Orthoclad, *Cricotopus bicinctus*, was also more abundant at these stations and Winner et al., (1980) found it to be very tolerant of heavy metal pollution.

Test station #1 had a stream condition index score of 14 in October 2002 and a score of 12 in March 2003 indicating that the site was impaired even though there was no strong indication that the impairment was caused by heavy metal pollution. The taxa richness and abundance of mayflies and dipterans along with physicochemical data at the station indicate that dissolved metals were not the primary cause of the impairment at the site (Figures 2-5; Tables 10-11). The impaired condition of the station can be attributed to a much higher Biotic Index score and lower Shannon Diversity Index score (Tables 7 and 8). The mayfly family Caenidae, which has a high Biotic Index, made up 19.45 percent of the sample in October 2002 and 24.51 of the sample in March 2003 and could be one of the causes for lower metric scores for the Biotic Index and Shannon Diversity Index.

4.4 Previous Evidence of Heavy Metal Pollution in Big Creek

The results of an impaired macroinvertebrate community in Big Creek below Scroggins Branch are not a surprise since previous studies have shown biological impairment and elevated levels of heavy metals in water, fish blood, and fish carcasses. Ryck (1974) sampled macroinvertebrates in Big Creek below Scroggins Branch before and after the Glover smelter started operations in 1968. This study found that the macroinvertebrate community changed from one dominated by pollution sensitive organisms of stonefly and mayfly groups before the smelter started operations to a macroinvertebrate community that was dominated by pollution tolerant organisms after operations commenced.

A macroinvertebrate bioassessment study conducted by ESP in 2000 found that Big Creek was partially impaired at a station about 1.4 miles downstream of Scroggins Branch for both the fall and spring 2000 sampling seasons. This Big Creek station had a stream condition index score of 14 for a March 27, 2000 sample and a score of 12 for a September 20, 2000 sample. There were some indications that these samples may have been impacted by heavy metal contamination since they had a low abundance of Heptageniid mayflies and a high abundance of Othocladinae chironomids, including the tolerant *Cricotopus bicintus*, even though no metals data was collected for this study (Table 12). The fall 2000 macroinvertebrate sample from Big Creek was also probably affected by some habitat alteration that had occurred at the site that had caused the substrate to be unstable.

A 1993 *Ceriodaphnia dubia* toxicity study, conducted by ESP, found acute toxicity (100% mortality) in a water sample from Scroggins Branch and chronic toxicity in a water sample from Big Creek 0.5 miles downstream of Scroggins Branch. Toxicity tests using fathead minnows (*Pimephales promelas*) were also conducted in this study, but no toxicity was found. During the toxicity study, dissolved zinc ranged from 737-787 ug/L and dissolved cadmium ranged from 23.7 to 35.2 ug/L in Scroggins Branch while dissolved zinc ranged from 46-59 ug/L and dissolved cadmium ranged from <2.0-2.4 ug/L in Big Creek 0.5 miles downstream from Scroggins Branch. The dissolved cadmium and zinc levels were similar to levels found in our current bioassessment study at Scroggins Branch and Big Creek station #3. Dissolved thallium ranged from 3.81-30.0 ug/L in Scroggins Branch and was elevated during the toxicity test study.

The U.S. Geological Survey monitored water quality, including dissolved metals, on Big Creek near Chloride, Missouri (Station #07036940) from 1966 to 1990. During this time period, levels were higher than the Water Quality Standards (MDNR 2000) for acute or chronic toxicity, 17 times for dissolved cadmium, 4 times for dissolved zinc, and 1 time for dissolved lead. Mean values were 13.20 ug/L for dissolved cadmium, 72.16 ug/L for dissolved zinc, and 4.41 ug/L for dissolved lead.

Dissolved metals data collected for the Glover smelter NPDES permit (MO-0001121) from November 1998 to August 2003 showed that there were elevated levels of cadmium, lead, thallium, and zinc downstream of Scroggins Branch (Table 13). There were no water quality standards (MDNR 2000) violations for cadmium, thallium, and zinc. Water quality standards violations for lead occurred 2 times at Big Creek #4, 4 times at Big Creek #3, and 1 time at Big Creek near Chloride, Missouri. The two violations at Big Creek #4 occurred in October and November 2000 and possibly could be attributed to air deposition from the Glover smelter. The lead violations at Big Creek #3 occurred on November 1998, October 2000, November 2000, and January 2003. The values for the January 2003 samples were highly elevated with an average value of 98 ug/L and maximum value of 162 ug/L. The one violation for lead at Big Creek near Chloride, Missouri also occurred in January 2003 and had an average value of 70 ug/L and maximum value of 74 ug/L.

Elevated levels of dissolved metals have been found in blood and carcass samples from fish collected from Big Creek. Schmitt and Caldwell (1997) found that cadmium and lead were elevated in fish blood and carcasses of Northern Hogsuckers (*Hypentelium nigricans*) downstream of Scroggins Branch compared to an upstream station near Hogan, Missouri. No bioaccumulation studies have been done on macroinvertebrates in Big Creek, but previous studies done in the Rocky Mountains and England have found elevated levels of heavy metals in macroinvertebrates (Burrows and Whitton, 1983; Kiffney and Clements, 1993). These studies showed mayflies were more susceptible to bioaccumulation of heavy metals than predatory taxa like stoneflies since most mayflies feed on *aufwuchs* that also contained elevated levels of heavy metals.

Table 12
Biological Metric Values, Biological Metric Scores, and Macroinvertebrate Composition per Station from Big Creek Macroinvertebrate Samples Collected During the Fall and Spring 2000 Sampling Season. Dominant Macroinvertebrate Families (DMF) are highlighted in bold.

Variable-Station	Big Creek #1, Test Station – Spring 2000	Big Creek #1, Test Station – Fall 2000
Macro Sample Number	00-10157	00-10174
Total Richness Value	88	65
Total Richness Score	3	3
EPT Taxa Value	25	13
EPT Taxa Score	3	3
Biotic Index Value	6.18	6.76
Biotic Index Score	3	3
Shannon Diversity Index Value	3.38	3.28
Shannon Diversity Index Score	5	3
Stream Condition Index (SCI)	14	12
% Ephemeroptera	15.57	6.63
% Plecoptera	0.98	0
% Trichoptera	4.18	4.24
% Dominant Macroinvertebrate Families (DMF; below)		
Chironomidae	**46.00**	**61.74**
Caenidae	**10.77**	2.28
Ceratopogonidae	**10.50**	**6.96**
Simulidae	**9.88**	**5.54**
Elmidae	**3.47**	**6.52**
Baetidae	0.53	**4.02**
% Other Macroinvertebrate Families and Groups		
Heptageniidae	0.62	0
Ephemerellidae	3.02	0
Orthocladinae	30.43	30.54
Cricotopus bicinctus	9.16	11.41
Tanytarsini	3.02	5.33

Table 13
Average and Maximum Dissolved Metal Values (ug/L) Collected for the Doe Run Glover Lead Smelter NPDES Permit (#MO-0001121) at Monitoring Stations in Scroggins Branch and Big Creek from November 1998 to August 2003. No dissolved thallium values were collected at Scroggins Branch (Outfall #005).

Parameter	**Scroggins Branch - Outfall #005**	**Big Creek #4 - Upstream Monitoring Point**	**Big Creek #3 – Water Quality Monitoring Point #004**	**Big Creek at Chloride – Downstream Monitoring Point**	**Water Quality Criterion GWWF***
Dissolved Cadmium Average Maximum	 17.86 302	 0.10 2	 1.74 8.0	 0.91 3	 Acute – 49 Chronic – 11.8
Dissolved Lead Average Maximum	 19.50 846	 0.87 25	 3.27 162	 2.38 74	 Acute – 104 Chronic - 16
Dissolved Thallium Average Maximum	 - -	 0.02 2	 0.21 10	 0.20 2	 **
Dissolved Zinc Average Maximum	 973 6880	 3.93 73	 65.24 264	 38.69 105	 Acute – 371 Chronic - 340

* Water quality criteria for a general warm water fishery, based on hardness of 125–200 mg/L $CaCO_3$ which applies to the Big Creek sampling stations.

** Thallium does not have acute and chronic water quality criteria. The human health–fish consumption criteria for Thallium is 6.3 ug/L and drinking water supply and groundwater criteria is 2 ug/L.

5.0 Conclusions

The 303(d) listed stream segment was biologically impaired in comparison to the upstream control station #4 and biological criteria reference streams from the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU). Big Creek test stations, including two samples collected during a previous study in 2000, had a fully sustaining stream condition index rating 1 time (11.11 percent) and a partial sustaining stream condition index rating 8 times (88.89 percent).

The null hypothesis that the macroinvertebrate community in Big Creek would not differ between longitudinal reaches was rejected since upstream control station #4 had full sustainability scores for both sample seasons.

The other null hypothesis that the macroinvertebrate community in Big Creek would not differ from similar sized reaches of biological criteria reference streams within the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU) was rejected. The upstream control station #4 and test station #2, during the fall 2002 sample season, had full sustainability scores. Test station #2 during the spring 2003 sample season and all other stations for both sample seasons had partial sustainability scores.

The macroinvertebrate community composition and elevated levels of dissolved metals at stations #2 and #3 indicate the biological community was being impaired by heavy metal pollution while other influences may contribute to the impaired condition at station #1. The upstream control station #4 biological metric scores were comparable to biocriteria reference streams in the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU) and the macroinvertebrate community composition indicated that it was not being impacted by heavy metal pollution.

Water data collected during this study and previous water samples indicate that the Doe Run Glover Lead Smelter is the source of heavy metal pollution. Water samples collected since the late 1960's demonstrate that elevated heavy metals in Big Creek below Scroggins Branch could be chronically affecting the macroinvertebrate community even though most values were below Water Quality Standards criteria (MDNR 2000). There was a dramatic decline in mayfly taxa richness and abundance and an increase in dipteran abundance at test station #2 and #3 compared to control station #4 and test station #1. Mayflies from Heptageniidae and Caenidae declined while dipterans from Orthocladinae, Empididae, and Tipulidae increased at stations #2 and #3.

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Appendix A

Missouri Department of Natural Resources
Bioassessment Study Plan
Big Creek, Iron County
July 29, 2002

Missouri Department of Natural Resources
Bioassessment Study Proposal
Big Creek, Iron County
July 29, 2002

Objectives

This study will assess the aquatic macroinvertebrate community in Big Creek upstream and downstream of the Doe Run Glover Lead Smelter which discharges (NPDES permit number MO-0001121) into Scroggins Branch, a tributary of Big Creek. Four miles of Big Creek have been placed on the 303(d) list for elevated levels of metals from discharges from the Doe Run Glover Smelter. The objectives of this study are to determine: 1) whether the aquatic macroinvertebrate community is being impacted downstream of Scroggins Branch relative to sections upstream of that area; and 2) whether the aquatic macroinvertebrate community of Big Creek is impaired relative to that of regional biocriteria reference streams.

Null Hypotheses

1) The macroinvertebrate community will not differ between longitudinally separate reaches of Big Creek.

2) The macroinvertebrate community in Big Creek will not differ from similar sized reaches of biological criteria reference streams within the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU).

Background

Elevated levels of metals such as lead, zinc, and cadmium in water and sediments can be toxic to aquatic organisms. Previous studies on Big Creek by biologists from MDNR, MDC, USGS, ENSR, Inc., and Hydrometrics, Inc. have found elevated levels of metals in water samples, sediments, fish tissue, and fish blood. In addition, macroinvertebrate taxa richness has been reported to be lower downstream of the Glover Smelter compared to upstream reaches. Metal intolerant macroinvertebrate taxa like mayflies were greatly reduced at downstream sampling sites. Our goal is to determine if Big Creek's water quality is still being impaired and to determine the distance of the impairment.

Study Design

General: Four Big Creek Stations will be surveyed. The general locations are as follows: 1) 1.6 miles upstream of the confluence of Scroggins Branch just east of Hwy 21 on a Doe Run property road (SW1/4, Sec. 35, T33N, R3E); 2) 0.10 miles downstream of the confluence of Scroggins Branch just east of Hwy 49 on a Doe Run property road (NW ¼, Sec. 11,T32N, R3E); 3) 0.45 miles downstream of the confluence of Scroggins Branch just east of Hwy 49 on a Doe Run property road (SW1/4, Sec. 11, T32N, R3E); and 4) 5.0 miles downstream of the confluence of Scroggins Branch at Hwy 49 road crossing (NW1/4, Sec. 35, T32N, R3E). The upstream sampling station and biocriteria reference streams in the Upper St. Francis/Castor Ecological Drainage Unit (EDU) will serve as controls and will be compared to the downstream sampling

stations. A longitudinal comparison of the Big Creek sampling sites will also be made to try to determine if the stream begins to recover from the discharge of the smelter.

Each station will consist of a length approximately 20 times the average stream width, and will contain at least two riffle areas, as outlined in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). To assess variability among sampling stations, stream discharge, habitat assessment, and water chemistry will be determined during the macroinvertebrate surveys. Sampling will be conducted in fall of 2002 (September 15 through October 15) and the spring of 2003 (March 15 through April 15).

Biological Sampling Methods: Macroinvertebrates will be sampled according to the guidelines of the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). Each of the sampling stations are "riffle/pool" predominant stream reaches; therefore samples will be collected from flow over coarse substrate, depositional (non-flow), and root-mat habitats. Each macroinvertebrate sample will be a composite of six sub-samples within each habitat.

Habitat Sampling Methods: Stream discharge will be measured at each sampling station with a Marsh-McBirney flow meter according to MDNR-WQMS-113. Stream habitat assessments will also be conducted within each study area according to the guidelines of the Stream Habitat Assessment Project Procedure.

Water Quality Sampling Methods: Water samples from all sampling stations and Scroggins Branch just upstream of it's confluence will be analyzed at the ESP laboratory for dissolved metals (cadmium, copper, iron, lead, zinc, calcium, and magnesium), chloride, TKN, ammonia nitrogen, nitrite plus nitrate nitrogen, total phosphorus, turbidity, and hardness. Field analyses will include pH, conductivity, temperature, and dissolved oxygen.

Laboratory Methods: All macroinvertebrate samples will be processed and identified according to the guidelines of MDNR-WQMS-209. Turbidity samples will be analyzed at the MDNR biological laboratory.

Data Recording and Analyses: Macroinvertebrate data will be entered in a Microsoft Access database according to MDNR-WQMS-214. Data analysis is automated within the Access database. Four standard metrics are calculated according to the SMSBPP: Total Taxa (TT); Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT); Biotic Index (BI); and the Shannon Index (SI) will be calculated for each sampling station. Additional metrics, such as quantitative Similarity Index for Taxa (QSI-T), Percent Ephemeroptera, Percent Chironomidae, or Percent Scrapers (PS) may be employed to discern differences in taxa between control and impacted stations.

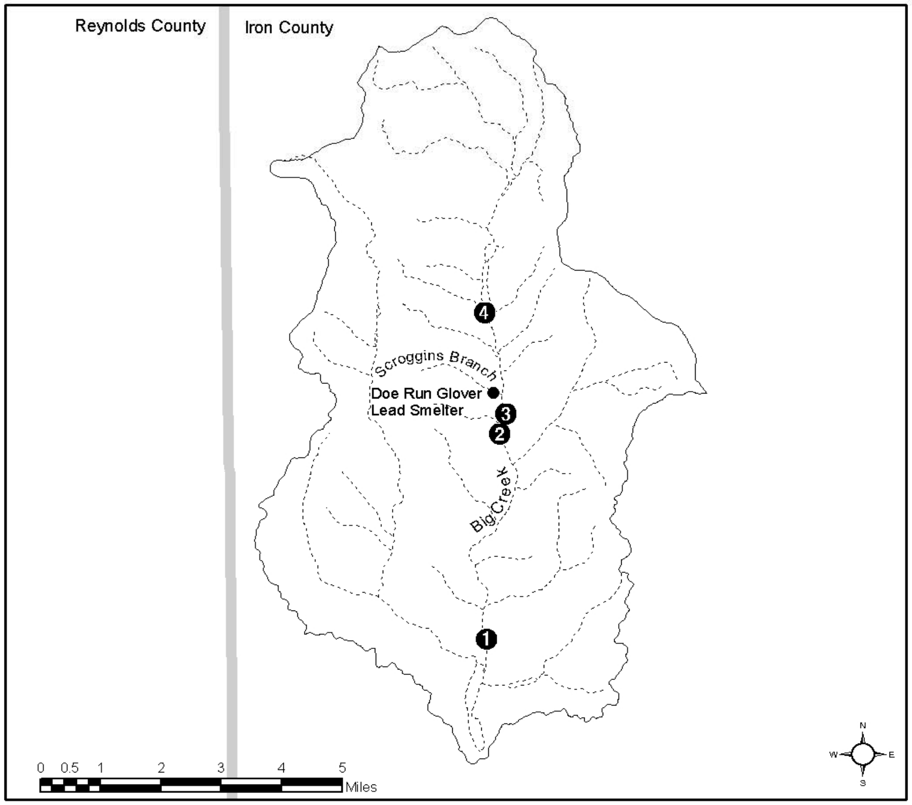
Macroinvertebrate data will be analyzed in two ways. First, a longitudinal comparison between the four sample reaches of Big Creek will be made. Secondly, the data from Big Creek will be compared to data collected from biocriteria reference streams in the Upper St. Francis/Castor Ecological Drainage Unit (EDU).

Data Reporting: Results of the study will be summarized and interpreted in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments:
Map of all sampling stations in this study

Big Creek Study Sites

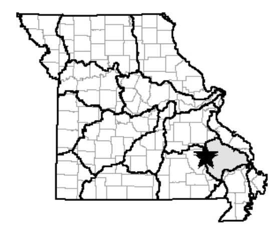


★ Sampling Location
County Boundary
Local Drainage
Stream/River

Local Drainage and Biologic Sampling Site Location

Ecolocial Drainage Unit (EDU) - An EDU is an area that contains a unique combination of habitats and organisms. Missouri is divided into 19 EDUs as shown in the inset map below. This site is located in the highlighted EDU.

Local Drainage - The local drainage area, also known as a 14 Digit Hydrologic Unit, is shown in the main map at left. This area is a portion of the local watershed. Missouri is split into over 1500 such units.



Ozark/Upper St. Francis/Castor Ecological Drainage Unit

Appendix B

Big Creek Macroinvertebrate Bench Sheets

October 2002 Samples (1 of 5)

Name	Big Creek #4 02-18116				Big Creek #3a 02-18117				Big Creek #3b 02-18118				Big Creek #2 02-18119				Big Creek #1 02-18120			
	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Acarina	28	2		30	15	3	1	19	5	1	1	7	8	2	2	12	18		13	31
Lumbricidae	4	2		6	2			2			2	2	1	1		2				
Lumbriculidae											1	1								
Planariidae	1			1													1			1
Tubificidae							1	1			2	2								
Allocrangonyx		1		1																
Caecidotea														1		1				
Caecidotea (Blind & Unpigmented)		1		1																
Hyalella azteca			48	48														2	51	53
Lirceus																	1			1
Orconectes luteus	*																*			
Orconectes peruncus	1			1																
Stygobromus	1	1		2		1		1												
Ancylidae			1	1																
Ferrissia																		1		1
Lymnaeidae																	1			1
Menetus			3	3															4	4
Physella			1	1			1	1		2		2							1	1
Sphaerium							1	1												
Acentrella	10	1		11	5			5	1			1	3			3	9			9
Acerpenna	2			2																
Baetis	9			9													12			12
Caenis anceps	18	16		34													2			2
Caenis latipennis	3	5	2	10	2	2		4		2		2		5		5	18	171	43	232
Caenis punctata			84	84																
Centroptilum			1	1										3		3		5	4	9
Eurylophella	1	2	32	35													1			1

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
TC = Total Count
* = Present

Name	Big Creek #4 02-18116				Big Creek #3a 02-18117				Big Creek #3b 02-18118				Big Creek #2 02-18119				Big Creek #1 02-18120			
	CS	NF	RM	TC	CS	NF	RM	TC	CS	NF	RM	TC	CS	NF	RM	TC	CS	NF	RM	TC
Hexagenia														1		1				
Isonychia bicolor	18			18	5			5					4			4	8			8
Leptophlebiidae	4	8	2	14																
Leucrocuta																	3			3
Procloeon		2	6	8															1	1
Stenacron	3	9		12																
Stenonema femoratum		111	6	117		1		1		6		6		2		2	1	11	3	15
Stenonema mediopunctatum																	7			7
Stenonema pulchellum	8	2		10													4			4
Stenonema vicarium	18			18																
Tricorythodes	11			11						1		1					3		2	5
Argia	9	17	4	30	18	6	39	63	9	15	19	43	4	24	2	30	5	3	2	10
Boyeria			*																*	
Calopteryx			1	1			5	5			1	1			2	2			2	2
Enallagma			4	4			10	10			7	7		1	11	12			10	10
Erythemis							3	3						2		2			*	
Gomphidae					2	5	1	8		4		4	1			1		2		2
Gomphus							1	1			2	2		6		6				
Hagenius brevistylus					2	2		4		1		1		5		5		2		2
Hetaerina					1		2	3												
Libellulidae										1	1	2								
Macromia							*				2	2			3	3				
Somatochlora																			*	
Stylogomphus albistylus	10			10	8			8	7			7	6	1		7	3			3
Acroneuria	2			2									1			1				
Leuctridae													3			3				
Neoperla	2			2	3			3	5			5	1			1	14	*		14
Perlinella ephyre														1		1		*		
Zealeuctra	3	11		14	3	1		4						3		3				

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Microvelia									1			1								
Trepobates											1	1								
Veliidae	1		1	2	1			1										1		1
Corydalus	1			1	2			2	3			3	2			2	*		*	
Nigronia serricornis									1		1	2					*			
Ceratopsyche morosa grp	3			3	10			10	4			4	43			43				
Cheumatopsyche	33			33	29			29	17	2		19	36		1	37	37		2	39
Chimarra					19	3		22	11	2		13	31			31	2		1	3
Helicopsyche	6	1		7	3			3	1			1	1			1				
Hydropsyche									2			2					28			28
Hydroptila						1		1		2		2								
Mystacides						1		1		1		1								
Nectopsyche						1		1		2		2			1	1				
Oecetis					4	3	25	32			2	2	1	1	23	25	2		3	5
Oxyethira					3		20	23	3			3	1	3	6	10				
Polycentropus	11	2		13	1		2	3	2		1	3		1		1		1		1
Triaenodes							19	19			9	9		2	54	56			12	12
Ancyronyx variegatus																			1	1
Berosus							10	10			7	7						4	1	5
Coleoptera	2			2																
Dubiraphia		2	2	4		3	25	28		2	11	13		8	3	11		15	2	17
Ectopria nervosa	3			3			1	1												
Helichus lithophilus	1			1			3	3			2	2								
Macronychus glabratus							1	1												
Microcylloepus pusillus	2		1	3	3		12	15			2	2	3	2	9	14	3		10	13
Optioservus sandersoni	13			13					1			1	2	1		3	14			14
Paracymus															1	1				
Psephenus herricki	18	16		34	13	2		15	8	2		10	11			11	13			13
Scirtes							5	5											5	5

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Ablabesmyia	1	5	1	7	1	11	4	16	2	34	3	39		48	20	68	2	1	1	4
Cardiocladius					1		1	2	6			6	3			3				
Chironomus																		2		2
Cladotanytarsus	6	36	4	46														16	1	17
Corynoneura	1	1	1	3	1	1		2		1		1	1			1	1		1	2
Cricotopus bicinctus	17		6	23	75	1	38	114	58		8	66	47	4	16	67			1	1
Cricotopus/Orthocladius	101		16	117	142	3	9	154	176	3	9	188	70	5	3	78	22	3	8	33
Cryptochironomus														3		3		1		1
Dicrotendipes		7	7	14	1	23	2	26	1	20		21		5		5	1	8	5	14
Endochironomus															1	1				
Krenopelopia													1			1				
Labrundinia			1	1			3	3		1		1			21	21				
Larsia						1		1							1	1				
Micropsectra																	1	1		2
Microtendipes	1	1		2	1			1									7	1	5	13
Nanocladius										8		8		1		1				
Nilotanypus					2			2	4			4	4	2	1	7				
Parakiefferiella	3	3	1	7		22		22		13		13						1	1	2
Parametriocnemus	1	1		2	9			9	4			4	9			9	6	1		7
Paraphaenocladius							1	1												
Paratanytarsus			2	2														1	11	12
Pentaneura													2			2	1			1
Phaenopsectra					3	3	3	9		19		19		44		44				
Polypedilum														1		1				
Polypedilum convictum grp	64			64	46	8		54	71			71	52	3	1	56	7		1	8
Polypedilum fallax grp						2	1	3		2	2	4			1	1		2		2
Polypedilum illinoense grp			1	1																
Potthastia	1			1																
Procladius						2		2		1		1		1		1		2		2

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Pseudochironomus		1	10	11						1		1						3	1	4
Rheocricotopus	1			1	9	1		10	1			1					1			1
Rheotanytarsus	36	1	4	41	27	1		28	25		1	26	22			22	16			16
Stempellinella			1	1																
Stenochironomus		1	1	2		1	8	9		2	4	6		4	1	5			5	5
Stictochironomus																		7		7
Tanytarsus	12	14	16	42	3	25	13	41	11	11	3	25	38	21	38	97	64	24	9	97
Thienemanniella	43	2	5	50	9			9	6			6	8		1	9	3			3
Thienemannimyia grp.	24	5	5	34	23	2	34	59	28	9	18	55	9	10	11	30	9	5	3	17
Tribelos						4	3	7		4		4	1	40		41		33	3	36
Zavrelimyia	1			1											1	1			1	1
Atherix											1	1								
Ceratopogoninae	4		10	14	2	21	1	24	1	3		4	2		2	4	9	4	43	56
Chlorotabanus																			*	
Chrysops														1		1				
Dasyheleinae									2	1		3								
Diptera					3			3			2	2								
Dixella			1	1			1	1												
Ephydridae	1			1																
Forcipomyiinae	2			2	1		1	2	1			1	1		1	2	2			2
Hemerodromia	13			13	23		2	25	29	2		31	31			31	3			3
Hexatoma	1			1	10	2		12	39	8	1	48	32		1	33	20	3		23
Simulium					17			17	50			50	83			83	2			2
Tabanus	5			5	3			3	5			5	15			15	2			2
Tipula	1			1	6			6	2		1	3	1			1				
undescribed Empididae					1			1												
Petrophila					1		1	2												

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March 2003 Samples (1 of 6)

Name	Big Creek #4a 03-18677				Big Creek #4b 03-18678				Big Creek #3 03-18679				Big Creek #2 03-18680				Big Creek #1 03-18681			
	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Acarina	6			6	1	2		3	20		1	21	2	1		3	38			38
Branchiobdellida			3	3	1			1												
Lumbricidae													1			1				
Lumbriculidae					1	3		4		4		4	1	2		3	2	1		3
Planariidae											1	1	1			1				
Tubificidae																		1		1
Caecidotea (Blind & Unpigmented)	7			7	29			29												
Crangonyx																			1	1
Gammarus							1	1												
Hyalella azteca			5	5			6	6										1	20	21
Lirceus					1		1	2	1			1								
Orconectes luteus			1	1	*	*	*										*	*		
Orconectes virilis			1	1																
Stygobromus														1		1				
Ancylidae						1		1												
Menetus										1		1								
Physella							*												*	
Pisidium																		1		1
Acentrella	9			9	8			8	19			19	1		1	2	3			3
Ameletus lineatus			1	1																
Baetidae					1		1	2	1			1								
Baetisca lacustris						1		1												
Caenis anceps		16		16	2	22		24												
Caenis latipennis	2	1	8	11	3	23	5	31	1		1	2		1	3	4	149	122	43	314
Centroptilum						2	2	4			1	1						1		1
Ephemerellidae	4		1	5																

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Eurylophella bicolor			6	6	4	9	7	20									1			1
Eurylophella enoensis			4	4			1	1										1		1
Heptageniidae	3		2	5	2		1	3									12	1		13
Isonychia bicolor	7		1	8	7		2	9	7		1	8	1			1	9			9
Leptophlebia			1	1			*			2	1	3						1		1
Paraleptophlebia					1		1	2												
Siphlonurus			1	1														2		2
Stenacron		1		1	1	2		3	1			1								
Stenonema femoratum	*	3	7	10	1	16	6	23	1	2	1	4	1	1		2	2	13	4	19
Stenonema mediopunctatum									1			1					14			14
Stenonema pulchellum	16		5	21	9		1	10	4		2	6	1			1	12		2	14
Stenonema vicarium	4		1	5	1			1									*			
Argia	2			2		2		2	4		6	10	2	1		3	2	2	2	6
Boyeria			*																	
Calopteryx							*												1	1
Enallagma			2	2		1		1			8	8			1	1				
Gomphidae														2		2				
Hagenius brevistylus						1		1							1	1				
Helocordulia																		*	1	1
Libellula											1	1							*	
Macromia															1	1				
Stylogomphus albistylus	1			1		1		1	5			5	1	1		2	2			2
Acroneuria	1			1			*						*							
Amphinemura	49		4	53	44		24	68	25		29	54	26		4	30				
Chloroperlidae	4			4	3			3					1	1		2				
Clioperla clio			1	1											1	1				
Helopicus nalatus																	*			
Isoperla	80			80	122		2	124	59		5	64	12			12	13		*	13
Leuctridae	57	5	3	65	55	3	12	70	1			1								

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Name	Big Creek #4a 03-18677				Big Creek #4b 03-18678				Big Creek #3 03-18679				Big Creek #2 03-18680				Big Creek #1 03-18681			
	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Perlinella ephyre														2		2	1			1
Prostoia	2			2																
Strophopteryx	9		2	11	3		1	4	8		5	13	6			6	1			1
Zealeuctra	1			1									1			1				
Hydrometra																			1	1
Microvelia							1	1			1	1								
Corydalus	*								2	*	*	2					3			3
Nigronia serricornis	1			1							*									
Sialis						*														
Agapetus					1			1												
Ceratopsyche morosa grp	1			1	1			1					1			1	17			17
Cheumatopsyche	44			44	52	2		54	10		3	13	3			3	69	1	2	72
Chimarra	19			19	20			20	5			5	1			1	2			2
Helicopsyche	4			4	2			2	1			1					6		1	7
Hydroptila	3		1	4		1		1		1	2	3			2	2	1		2	3
Mystacides		1		1																
Nectopsyche															2	2				
Neureclipsis															3	3				
Oecetis									1		1	2	2		13	15	5		3	8
Oxyethira							1	1	1		14	15	1		28	29	2		7	9
Polycentropus	3			3	8	1	2	11	2		2	4	4	1		5				
Ptilostomis										1		1								
Pycnopsyche			1	1			*				2	2			1	1			1	1
Rhyacophila					1	1		2												
Triaenodes						1	1	2			4	4			2	2		1	1	2
Berosus						1	1	2										3		3
Dubiraphia	1			1		4		4							1	1		4	1	5
Ectopria nervosa										1		1								
Enochrus											1	1								

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Microcylloepus pusillus											1	1	3		22	25			4	4
Optioservus sandersoni									2			2					6			6
Psephenus herricki	1			1	1	3		4	1			1					3			3
Scirtes							1	1												
Stenelmis						2		2	1			1		1		1	58	1		59
Ablabesmyia		3	3	6		33	6	39		5	2	7		22		22		29	3	32
Cardiocladius									1			1					3			3
Cladotanytarsus	3	129	1	133		21	2	23		7	1	8						3	2	5
Corynoneura	3	2	17	22		7	17	24	1	3	12	16	1	5	2	8			5	5
Cricotopus bicinctus	2		17	19	2	4	6	12	29	2	56	87	14	14	82	110	6		17	23
Cricotopus/Orthocladius	49	5	116	170	24	23	48	95	164	9	64	237	28	18	47	93	50	5	119	174
Cryptochironomus	1	1		2		3		3												
Diamesa									2			2								
Dicrotendipes		1	7	8		1	2	3	1	4	2	7		4	1	5		1	1	2
Diplocladius									1			1								
Djalmabatista														2		2				
Endochironomus						1		1												
Eukiefferiella	4			4	7		2	9	19	1	1	21	3	1		4				
Hydrobaenus			2	2					1			1								
Labrundinia			4	4		1	5	6		1	2	3		1	1	2			2	2
Micropsectra	1			1					1			1								
Microtendipes		1		1	2			2												
Nanocladius					1			1	2			2		5		5	1			1
Nilotanypus									1	1		2							1	1
Orthocladius (Euorthocladius)									4		1	5								
Orthocladius (Symposiocladius)							1	1												
Parakiefferiella		21	3	24		29	1	30		1		1		2		2		2		2
Paramerina			1	1																

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Paraphaenocladius	1			1						1		1								
Paratanytarsus			37	37		3	2	5		1	6	7		2		2		2	10	12
Paratendipes														1		1			1	1
Phaenopsectra		1		1		6	1	7		2		2								
Polypedilum convictum grp	77			77	59	2	11	72	38		4	42	13	2		15	10		2	12
Polypedilum fallax grp																			1	1
Polypedilum illinoense grp	1		1	2																
Polypedilum scalaenum grp																		3		3
Potthastia														1		1	1			1
Procladius						1		1						1		1		4		4
Psectrocladius		2	1	3		2	3	5		2	5	7	1	9	1	11		3	1	4
Pseudochironomus		1		1														1	1	2
Rheocricotopus	5	1	8	14	3		5	8	8	1	9	18	4			4	1			1
Rheotanytarsus	11		14	25	9	1	20	30	8		8	16	3		28	31	9		9	18
Robackia	8			8	2			2					1			1	1			1
Stempellinella	2	4	1	7		9	1	10										2		2
Stenochironomus														2		2				
Stictochironomus		1	1	2										1		1		12		12
Sympotthastia	11		2	13	9		4	13	40	5	41	86	18	8	2	28	7	2	6	15
Tanytarsus	22	25	13	60	22	13	15	50	4	7	2	13	9	22	4	35	40	19	27	86
Thienemanniella	1		3	4		1	2	3	1		2	3			1	1	1		2	3
Thienemannimyia grp.	7	8	24	39	13	14	14	41	11	7	9	27	11	28	6	45	12	14	18	44
Tribelos														5	1	6		21		21
Tvetenia									1			1								
Zavrelimyia		1	1	2		1		1										2		2
Ceratopogoninae	1	5	1	7		6		6	3	1		4	1	8		9	1	3	2	6
Clinocera	21	2	1	24	20	1		21	20	1	1	22	21	2	1	24	2			2
Dasyheleinae														2		2		2		2
Diptera						2		2												

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	CS	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**	**CS**	**NF**	**RM**	**TC**
Erioptera		1		1		1		1												
Gonomyia						2		2												
Hemerodromia	4			4	6	1	1	8	24	1	3	28	13		3	16	5			5
Hexatoma	3	3		6	2			2	16		2	18	53	27	3	83	54	4	2	60
Prosimulium	20			20	18	1	2	21	14		2	16	1		2	3	1			1
Simulium	4			4	3		1	4	11		4	15								
Tabanus	4			4	4		*	4	2	*		2	1	1		2	3			3
Tipula	9	1	*	10	2		*	2	2		*	2	*	1		1	*	*		
undescribed Empididae										1		1								
Petrophila	1			1																

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